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Queuing theory based service performance evaluation under H2H and M2M blending traffic arriving

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Abstract

Machine type communications (MTC), which mainly refer to the communications between Machines (M2M), draw great attention these days. Blending traffic arriving, M2M together with the traditional H2H (Human to Human), brings new problems and should change the network technologies in several aspects. Based on queuing theory, this paper models blending traffic and evaluates the service performance. The M2M and H2H present very different characteristics, so we introduce two metrics, the bursty and the size of batch, to model different types of services mathematically. Concepts Basic Service and BBU are proposed to solve the problem of bandwidth allocation under the blending arriving. BBU, basic bandwidth unit, is defined as the demanding bandwidth of basic service, while Basic Service refers to M2M shortest data service. Any other services are believed to occupy integral multiple of BBU. We get the numeric solutions of our queuing model. In performance analysis, the features of new M2M services are specially addressed. The simulations present the scenarios when MTC come into use, also show that some technologies proved to be effective to H2H services, such as bandwidth reservation which should be optimized under the blending arriving.

*Keywords:*MTC; BBU; queuing theory; M2M; networks

1.Introduction

Machine Type Communications (MTC) mainly refer to the communications between machines (M2M), MTC is considered the most promising services [1]. MTC services will share carrier networks with traditional H2H services. It is predicted that ratio of MTC traffic to H2H service will be 30 in 2020. .

This paper focus on the network performance evaluation under blending M2M and H2H traffic arriving. Queuing model of H2H communications has been scientific research subject for a long time [2] [3], however, that of MTC is in its very initial step, and is hardly reported in current literatures. The arrival, network serving and bandwidth allocation of MTC services are important research topics. Main type of MTC traffic is data, whose arrival presents strong bursty and great mass. M2M data service has a characteristic of small flow which makes its serving rate obviously higher than that of H2H. Cheng

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Yanhong proposed a bandwidth allocation scheme between uplink and downlink which is based on bandwidth sending mechanism [4]. Zhen Haocong put forward a novel dynamic bandwidth allocation method supporting multi-services for CDMA networks [5]. Existing bandwidth allocation methods don't consider the H2H and M2M blending traffic arriving. This paper proposes the concepts of Basic Service and BBU to solve the problem in bandwidth allocation. BBU, basic bandwidth unit, is defined as the demanding bandwidth of basic service, while Basic Service refers to M2M shortest data service. Any other services are believed to occupy integral multiple of BBU.

In this paper, we use variable intensity batch arrival to model arrival of blending service，variable serving rates to tell the difference between MTC and H2H services. Bandwidth allocation of blending services is performed by BBU allocation algorithm. This paper establishes a discrete time queuing model and gets its numerical solutions. We compare the features of H2H and M2M. It is illustrated that, some technologies proved to be effective to H2H services, such as bandwidth reservation, should be optimized under the blending arriving to meet the QOS requirements of M2M and H2H services.

Other parts of the paper are organized as follow. Part 2 builds up network model of blending services based on queuing theory. Part 3 presents the results of simulations

2.Network model of blending services

2.1.Service Classification

H2H services can be simply divided into three priorities: voice service (noted as Hh), video streaming (Hm) and data service (Hl). MTC services are described as seven classes and 35 types in the 3GPP. This paper we mainly consider two important MTC services, the first one is data service (Ml) that is small flow, not sensitive to delay and with short active time, such as data sent by retailing machines. The other is monitoring service (Mm) that is large data flow, requiring low delay and running long time. We divide blending service into three priorities, namely high priority voice service (Hh), medium priority video service (Hm and Mm) and the low priority data service(Hl and Ml). We compare network performance of H2H services with that of blending services under the same BBU distribution mechanism.

2.2.Queuing Model

We consider the future network scenarios, in which IMS

(IP multimedia subsystem) is taken as the framework of backbone network, so, only PS services should be counted. We establish discrete time queue system [6] which is packet-level model, as illustrated in Fig. 1. H2H and MTC services are divided into three different priorities by group classifier. Total bandwidth is divided into BBUs of the same size, and reservation mechanism is used. BBU allocation follows absolute priority scheduling. We use late queuing model, that is, the beginning and the ending of network serving occur at the beginning of a time slot, and traffic arrives at the end of a time slot. Arrival interval independent and subject to geometric distribution. We assume batch arrival, different batch sizes descript different services, serving time also follows geometric distribution and arrival intervals are independent of each other.

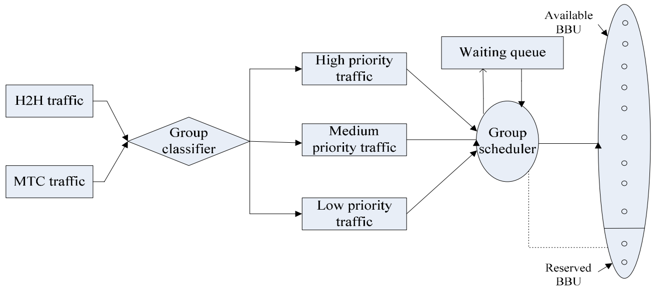

Figure 1. Queuing System Model.

Different batch sizes represent different services [7]. We assume that batch sizes of Hh and Hm subject to Poisson process with some volatility. Batch size of Hh is given by $Source\_h = Eh + Burst\_h$, where $Source\_h$ is batch size of Hh, Eh is Poisson process with mean Zh, $P\{X = Eh\} = (Zh^{Eh} / Eh!)e^{-Zh}$ $Eh = 0,1,2,3...$, $Burst\_h$ presents the bursty which is a random integer between one and Ph. The arrival of Hm has the same distribution with Hh, whereby different parameters. Pareto distribution is used to model batch size of Hl, according to self-similarity of data traffic.

We only consider data and video traffic of MTC in this paper. Batch size of Mm is fluctuated around constant Mv and we mix Mm and Hm to get medium priority business. Because Ml has a characteristic of strong bursty, $2-MMPP$ is taken to model Ml. $2-MMPP$ is two-state Markov modulated Poisson process, parameters set is $(u_1, u_2, \lambda_1, \lambda_2)$. Parameters $u1$ and $u2$ are state transition probabilities. λ_1 and λ_2 are arrival rates in two different states.

In our model, the total number of BBUs is dynamically selected following uniform distribution to simulate the actual network running environment, in which noise and interference and other problems change the network effective bandwidth constantly [8].

Mean bandwidth allocation method is adopted which allocates bandwidth according to the mean demanding bandwidth of a service. The number of BBUs that voice service needs is Bh, that of video service is Bm, Blm is that for H2H data service.

If only H2H traffic is considered, the system is stable when

$$\rho_1 = \frac{(Bh*Ah + Bm*Am + Blh*Al)*p1}{Tbbu*p2} < 1 \quad . \tag{1}$$

Ah, Am, Al are mean batch sizes of different H2H services. $Tbbu$ is mean number of BBUs. The probability of batch arrival and batch departure are given by p_1 and p_2.

For blending arrival, system is stable when

$$\rho_2 = \frac{(Bh*Ah + Bm*Tam + Blh*Al + Blm*Aml)*p1}{q1*Tbbu*p2h + q2*Tbbu*p2m} < 1 \quad . \tag{2}$$

Tam is mean batch size of medium priority service. Aml is mean of batch size of MTC data service. Consider MTC data service has characteristic of small flow, serving rate $p2m$ of Ml is higher than service rate $p2h$ of other services. Ratio of Batch size of Ml and total mass is $q_2 = \frac{Aml}{Ah+Tam+Tal}$, $q_1 = 1 - q_2$, $Tal = Al + Aml$, $p2m$ is serving rate of MTC data service, $p2h$ is service rate of other services.

When $\rho_1 = \rho_2$ is satisfied, we compare network performance of H2H service and blending service (H2H and MTC) under the same bandwidth allocation mechanism. Considering mathematical solution of queuing model is extremely complex, we get the numerical solution.

2.3.Allocation Strategy

This paper adopts static priority scheduling strategy shown in Fig.2. Dynamic BBU reservation mechanism is deployed to ensure QoS of high and medium priority services. The number of reserved BBUs is determined by the arrival of high and medium priority services in previous time slots, which effectively increases the utilization rate of BBUs.

We set multi-threshold buffer queue for services which arrive without BBUs accommodating [9]. The queue is divided into three parts: the first part shared by high, medium and low priority services, the second part only for high and medium priority services, the third part designed for high priority business privately. Queue length of high priority service is small, and queue of MTC data service is longest.

3.Mulations and analysis

3.1.ulations of Traffic Source

For H2H, the ratio of mean batch size of high, medium and low priority services is set to be 5:1:10. The numbers of arrived packets for three types of services and the numbers of BBUs they cost respectively are shown in Fig.3 and Fig.4.

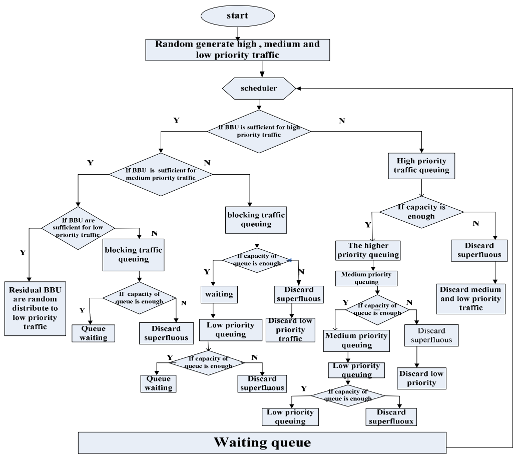

Figure 2. Static priority scheduling.

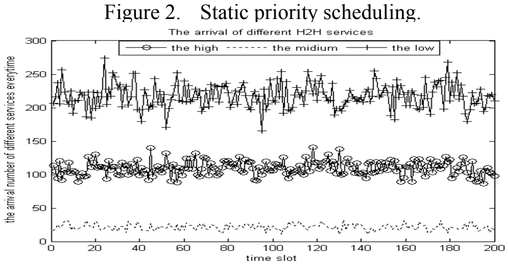

Figure 3. The arrival of different H2H services.

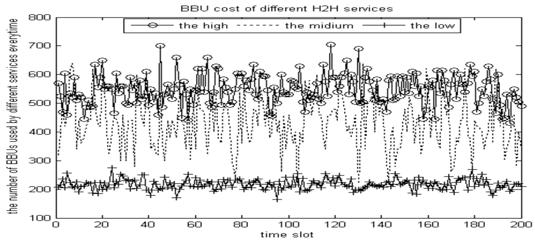

Figure 4. BBU cost of different H2H services.

Obviously, when only H2H services are considered, data service arrival is greatest and video arrival is least. However, voice and video service require more BBUs than data service. And also the number of BBUs required by voice service fluctuates sharply. It can be concluded that bandwidth requirement of data service is limited; voice and video services eat most of bandwidth in current network.

For H2H and M2M blending traffic, the ratio of mean batch size of Ml and Hl is set to be 9:1, and the ratio of mean batch size of Mm and Hm is taken as 2:1. Network serving time of MTC data service is relatively short because of mall flow characteristic. So Ml has a highest serving rate in model.

Service arrival and BBU requirement under the blending arriving are shown in Fig. 5 and 6.

Traffic of data increases dramatically and presents strong bursty as MTC join in current network. As a result, bandwidth requirement of data service far more than voice and video services. It can be predicted that data service will replace real-time services, such as the existing voice service, to become the biggest bandwidth demander in future. To meet the QoS requirement, bandwidth allocation for blending service attracts a lot of attentions.

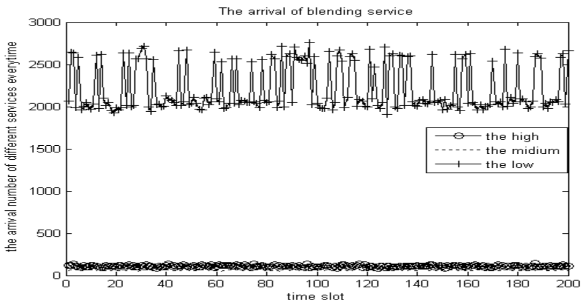

Figure 5. The arrival of blending service.

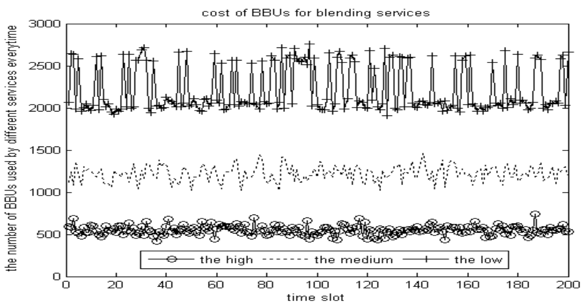

Figure 6. cost of BBUs for blending services.

3.2.ork Performance evaluation Of H2H Services

We use the same bandwidth allocation mechanism when $\rho_1 = \rho_2$ to observe network performance of different business arrivals. Packet-level model is established, blocking probability is the ratio of lost packets to all arrival packets, the lost dues to overflow of buffer queue, lost packets caused by transmission errors are not counted.

We get the average waiting queue length and blocking probability of three types of services after ten times simulation. It is shown in table 1.

Table1 show that blocking probability of high and medium priority business is very low under absolutely priority scheduling, which completely meets QoS requirement. However, for low priority service, average queue length is big and blocking probability of is relatively high, because higher priority voice and video services get bandwidth in advance, great number of low priority services are blocked.

Table I Parameters Of Different Priority SERVICES

	H2H services		**Blending services**	
	Average queue length	***Average block probability***	***Average queue length***	***Average block probability***
High priority	0	0	0	0
Medium priority	1.1	0.0014	0.012	0
Low priority	42.45	0.1235	169.23	0.1531

In order to measure performance of BBU reservation mechanism, we observe the utilization of reserved BBUs, seen in Fig.7.

Fig.7 depicts reserved BBUs are mainly used for medium priority business, high priority service costs little. Medium priority service costs reserved BBUs in a burst way. Visibly, the utilization of BBUs is low although we deploy dynamic BBU reservation, more than half of reserved BBUs remains idle. BBU reservation can reduce blocking probability of high and medium priority businesses, however, it wastes resources.

3.3.ork Performance Analysis Of Blending Services

The same BBU distribution mechanism and same simulation way described in last part are applied to the situation of blending traffic arriving. Mean waiting length and mean blocking probability are seen in Table 1.

When MTC services enter the existing network, data service dramatically increase, however high priority services will not be easily blocked due to the absolute priority scheduling and the queue length is almost zero. Ml service is massive and with strong bursty, however, its serving rate is higher than others, so average blocking probability of data is not increasing obviously.

Fig.8 shows the utilization of reserved BBUs. It can be found that high priority service hardly use reserved because there are large number of low priority data services after MTC join in the network. Absolute priority scheduling makes a large number of reserved BBUs remain idle, it should be optimized.

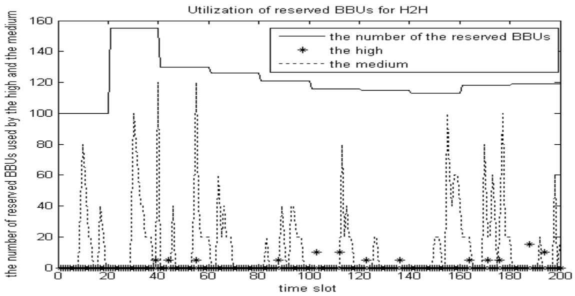

Figure 7. Utilization of reserved BBUs for H2H

4.Nclusion and propect

This paper focus on modeling and evaluating performance of blending traffic based on queuing theory. Simulation results show that voice service loses its main position when MTC join in the current networks, and data service will increase greatly. MTC traffic has characteristics of massive and strong bursting, however, MTC data service also has small flow characteristic and its serving rate is higher than others. So average blocking probability of data service will not increase after M2M joining networks. BBU reservation and priority scheduling should be optimized when M2M enter the networks.

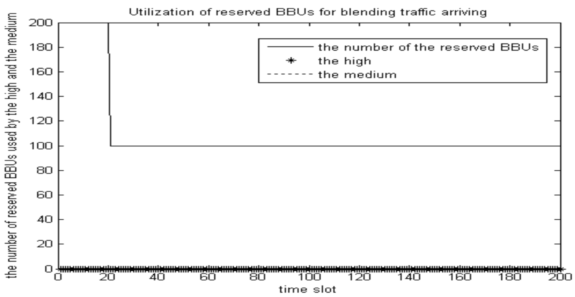

Figure 8. Utilization of reserved BBUs for blending traffic arriving

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